Stormwater Action Monitoring - Effectiveness Studies

Progress Report #5

Evaluation of Hydraulic Control Approaches for Bioretention Systems

Prepared For:

Contact Name:	Keunyea Song
Lead Entity Jurisdiction	Washington State, Department of Ecology
Department	Stormwater Action Monitoring
Address	P.O. Box 47600
City, Washington, Zip Code	Olympia, Washington, 98504-7600
Phone Number	(360) 407-6158

Prepared By:

Washington State University
Puyallup Research and Extension Center
2606 W Pioneer Ave
Puyallup, WA 98371
253-445-4523

Geosyntec Consultants
920 SW Sixth Ave
Suite 600
Portland, OR 97205
971-271-5912

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Project Status Summary

General Information

Contract / Grant Agreement Number:	IAA No. C2000041
Project Title:	**Evaluation of Hydraulic Control Approaches for Bioretention Systems**
Organization:	Washington State University
Project Managers:	Anand Jayakaran, Washington State University Leon Li, Geosyntec Consultants
Reporting Period:	January 1, 2022 to April 30, 2022

Brief description of Tasks and Achievements for current report period.

Task 1: Project Planning and QAPP Development

Percent Complete, Full Project:	100%
All deliverables to be completed:	Deliverables 1.1 to 1.3
Deliverables completed in **previous** reporting periods:	Deliverables 1.1 to 1.3
Deliverables completed in **this** reporting period:	None
Description of Achievements:	Deliverable 1.1: Meeting notes from TAC Kickoff Call Deliverable 1.2. Draft QAPP Deliverable 1.3: Final QAPP
Challenges faced during **this** monitoring period:	None to report

Task 2: Installation and Startup

Percent Complete, Full Project:	100%
All deliverables to be completed:	Deliverables 2.1 to 2.3
Deliverables completed in **previous** reporting periods:	Deliverables 2.1 to 2.3
Deliverables completed in **this** reporting period:	None
Description of Achievements:	Deliverable 2.1: Tables of equipment purchases Deliverable 2.2: Installation photolog Deliverable 2.3: Installation and Startup Report
Challenges faced during **this** monitoring period:	None to report

Task 3: Monitoring and Study Implementation

Percent Complete, Project Phase 2:	66%
Percent Complete, Full Project:	83%
All deliverables to be completed:	Deliverables 3.6 during Phase 2
Deliverables completed in **previous** reporting periods:	Deliverable 3.1: Progress Report #1 Deliverable 3.2: Progress Report #2 Deliverable 3.3: Progress Report #3 Deliverable 3.4: Progress Report #4
Deliverables completed in **this** reporting period:	Deliverable 3.5
Description of Achievements:	Completion of water quality event #5 and special event #3
Challenges faced during **this** monitoring period:	Power outage on 3/9/22 led to rescheduling of sampling event 5 Multiple CTD sensors failed, and supply chain issues extended down time Hydraulic residence time test had to be repeated due to data logging error

Task 4: Modeling Study

Percent Complete, Project Phase 2:	0%
Percent Complete, Full Project:	0%
All deliverables to be completed:	Deliverable 4.1 Modeling Study Plan Deliverable 4.2 Modeling Study Report
Deliverables completed in **previous** reporting periods:	None
Deliverables completed in **this** reporting period:	None
Description of Achievements:	None to report
Challenges faced during **this** monitoring period:	None

Task 5: Reporting and Communication of Findings

Percent Complete, Project Phase 2:	0%
Percent Complete, Full Project:	20%
All deliverables to be completed:	Deliverable 5.2 Final presentation to Stormwater Workgroup Deliverable 5.3 Final Report Deliverable 5.4 Data submittal to Ecology Deliverable 5.5 Fact Sheet
Deliverables completed in **previous** reporting periods:	Deliverable 5.1. Interim Presentation
Deliverables completed in **this** reporting period:	None
Description of Achievements:	None to report
Challenges faced during **this** monitoring period:	None

1 Introduction

This progress report documents the third monitoring period of the Stormwater Action Monitoring (SAM) Effectiveness Studies project Evaluation of Hydraulic Control Approaches for Bioretention Systems (Project). Progress Report #5 covers monitoring activities completed between January 1, 2022 and April 30, 2022. This period will be referred to as Monitoring Period #5. All monitoring activities were completed according to the Quality Assurance Project Plan (QAPP) dated August 20, 2020, with some noted modifications.

This report fulfills deliverable 3.5 of the Interagency Agreement effective September 9, 2019.

2 Continuous Monitoring Data

Continuous monitoring data were collected throughout Monitoring Period #3. Table 1 presents a summary of continuous monitoring data and data gaps. These data will be presented in more detail and analyzed as part of the Interim Presentation and the Final Report.

Table 1. Continuous data collected during the monitoring period

Data Stream	Logging Interval	Data Gaps
Precipitation	5-minute	None
Cistern Water Level	5-minute	None
Mesocosm Inlet Flow	5-minute	None
Mesocosm Outlet Flow	5-minute	2/21/22-2/28/22 reservoirs off due to freezing weather
Ponding Depth	5-minute	1/1/22- 3/7/22 multiple sensor failures
Soil Moisture[1]	5-minute	None

[1] Soil moisture data are only collected for the six fully instrumented mesocosms

3 Water Quality Event #5

3.1 Sampling Overview

Water quality event #5 was completed on April 6, 2022. During this event, dosed stormwater runoff was routed to the six fully instrumented mesocosms and to the influent monitoring point. During water quality event #1, monitoring data indicated that influent pollutant concentrations were substantially lower than the high pollutant dosing targets from the QAPP for TSS, total copper, and total zinc. Following water quality event #1, the research team agreed that precise pollutant concentration targets would be difficult to achieve due to variability in stormwater quality from the facility catchment and due to variable settling of pollutants in the two cisterns. To limit influent water quality variability from storm to storm, the research team agreed to use the same dosing approach for all future storms while also modifying the mixing approach in the cistern to limit particulate settling. Accordingly, cistern dosing was conducted using the same dosing that was used during water quality event #1.

Based on observations during water quality event #1, modifications were made during water quality event #3 to limit settling of Sil-co-Sil 106. Specifically, an additional mixing pump was added to the bottom of the cistern and ran continuously throughout the duration of the event. This approach reduced Sil-co-Sil 106 settling, was used in water quality events #2,3, 4, and 5, and will be used in all future water quality events.

Water was routed to the mesocosms and inlet point for four hours to represent a high intensity storm as presented in Table 9 of the QAPP. Flow-weighted composite samples were collected for the duration of the four-hour event and then overnight until the following morning. Each sample aliquot was 350 mL and was pumped into 20 L glass composite sampling containers. Following the completion of sampling, on the morning of April 7, 2022 the composite samples were delivered to ARI Labs where samples were mixed, split using a churn-splitter, and then analyzed for parameters listed in Table 11 of the QAPP.

3.2 Water Quality Data

Laboratory analytical results are summarized in Table 2 and full results will be submitted as part of the Final Report. Analytical results for total and dissolved zinc were low in effluent from some of the mesocosms, with a total of five values below detection limits and another three between the detection limit and the reporting limit.

During previous water quality events, it was observed that the coloration of effluent samples from some mesocosms were different from the others, likely due to higher DOC concentrations. The laboratory analysis results also showed that the dissolved copper effluent concentrations from these mesocosms had higher dissolved copper concentrations than the influent concentrations. Based on these visual observations and the importance of DOC in binding dissolved copper, we decided to have samples analyzed for DOC. DOC is an important component in the binding up of dissolved copper, and mitigating its toxic effects on downstream biota. Additionally, this would also enable comparison of data from this study with a companion SAM that recently concluded, conducted using similar methods on 16 bioretention cells.

Table 2. Water quality results for TSS and metals

Location	**TSS**	**Total Kjeldahl Nitrogen**	**Nitrate-Nitrite**	**Total Phosphorus**	**Orthophosphorus**	**Copper, total**	**Copper, dissolved**	**Zinc, total**	**Zinc, dissolved**	**Dissolved Organic Carbon**
Units	mg/L	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L
Influent Target[1]	120	3[2]		0.4	NA	40	NA	150	NA	N/A
Influent	76	1.4	2.88	0.84	0.270	45.9	3.49	265.0	80.7	1.85
12: Standard BSM, outlet controlled	1.	1.2	1.76	0.37	0.324	9.02	7.86	< 2.92[3]	< 2.92[3]	5.79

Location	TSS	Total Kjeldahl Nitrogen	Nitrate-Nitrite	Total Phosphorus	Orthophosphorus	Copper, total	Copper, dissolved	Zinc, total	Zinc, dissolved	Dissolved Organic Carbon
33: Standard BSM, media controlled	10	1.1	2.38	0.51	0.498	5.49	4.77	3.40[4]	< 2.92[3]	5.47
22: Mature BSM, outlet controlled	2	0.7	1.88	0.06	0.039	9.11	8.26	< 2.92[3]	< 2.92[3]	4.47
13: Mature BSM, media controlled	<1[3]	0.7	2.33	0.04	0.023	4.60	4.51	3.10[4]	< 2.92[3]	3.43
15: Alternative BSM, outlet controlled	4	<0.5[3]	1.46	0.06	0.045	2.12	1.70	< 2.92[3]	< 2.92[3]	1.96
34: Alternative BSM, media controlled	9	<0.5[3]	1.88	0.06	0.053	2.58	2.17	< 2.92[3]	< 2.92[3]	2.14

[1] Influent target values are from the QAPP for high pollutant.
[2] The QAPP presented an influent target of 3 mg/L for total nitrogen which is the sum of nitrate-nitrite and total Kjeldahl nitrogen.
[3] Values were below the detection limit
[4] Values were between the detection limit and the reporting limit.

4 Special Testing Event #3

4.1 Testing Overview

Special testing event #3 was completed following the completion of water quality event #5. This consisted of hydraulic conductivity testing which was completed on April 7th, followed by the hydraulic residence time monitoring which was completed on April 20th. The hydraulic residence time testing was delayed due to equipment issues described in Section 4.2.

4.2 Hydraulic Residence Time Testing

Hydraulic residence time testing was completed according to the approach presented in the QAPP, with some minor modifications. To limit the potential for ion interference, the research team used potassium bromide instead of $MgCl_2$ as the conservative tracer. The weir box for each of the fully instrumented mesocosms and the influent sampling point was dosed with 4 L of a solution with 4200 mg/L KBr. The transfer pump in the cistern was configured to convey water at a rate of 28 L/minute instead of 19 L/minute which was proposed in the QAPP. This higher flow rate was used to induce hydraulic differences between outlet-controlled and media-controlled mesocosms which are more apparent at higher flow rates. Flow was conveyed to each mesocosm for approximately 75 minutes before and then for 180 minutes after the dose was applied. Electrical conductivity in mesocosm effluent was recorded on a 1-minute logging frequency using Oakton PC450 handheld electrical conductivity meters.

This test was initially done on April 7, but due to some equipment failures in mesocosm 12 and 22, it was determined that the test should be repeated to ensure a complete dataset. All 6 of the fully instrumented mesocosms were dosed with the 4L of 4200 mg/L KBr as outlined above, but only the data from mesocosm 12 and 22 were recorded due to equipment availability.

Conductivity data from this testing are presented in **Figure 1**. Further analysis and discussion of these data will be presented in the Final Report.

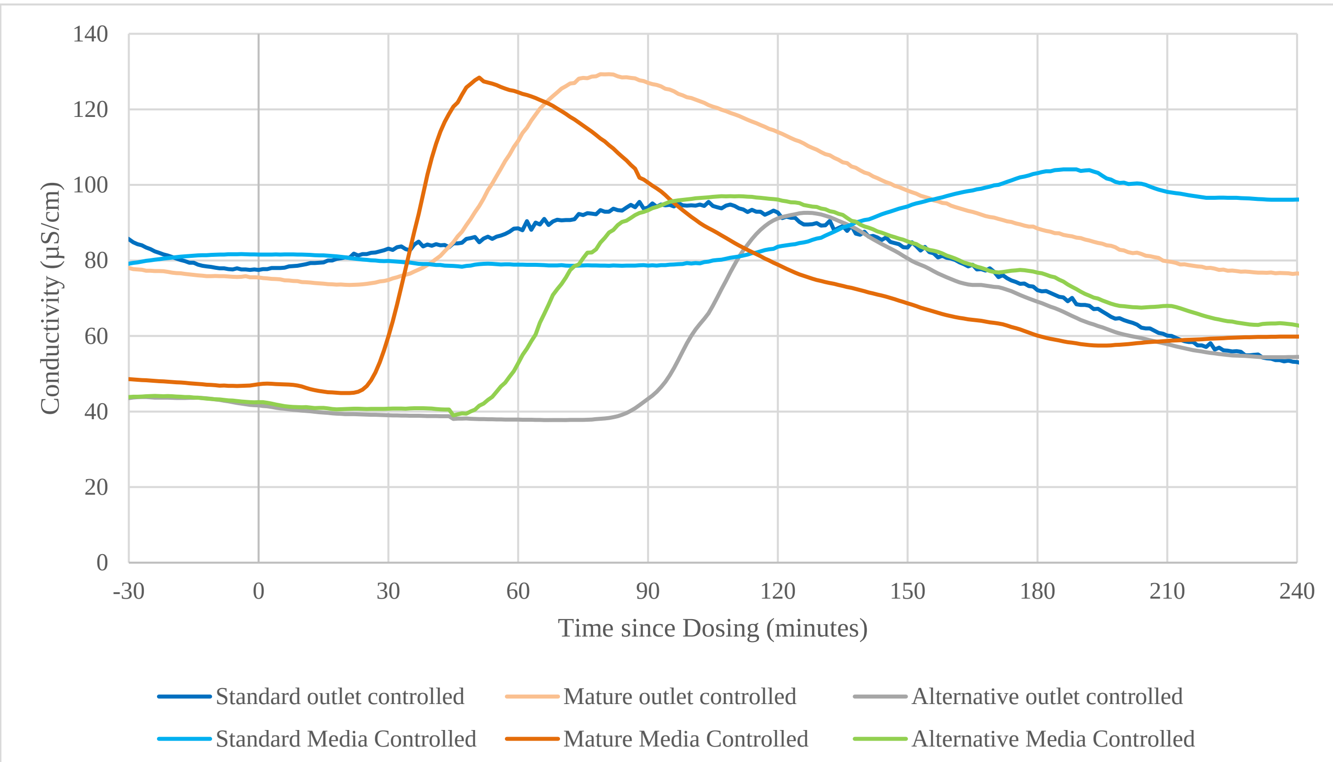

Figure 1: Hydraulic residence time results

4.3 Hydraulic Conductivity Testing

Hydraulic conductivity testing was completed in accordance with the method presented in the QAPP, with some minor modifications. Briefly, the outlet valve from each mesocosm was closed and then water was conveyed to each mesocosm until it was at least nine inches deep. The QAPP proposed filling each mesocosm to brim full, however, to save time and water, filling to nine inches of ponding depth was deemed adequate to initiate testing. This testing was completed immediately after finishing residence time testing, so some of the mesocosms still had shallow ponding at the start of hydraulic conductivity testing. The inlet valve to each mesocosm was then closed, and then outlet valves were adjusted to that all mesocosms discharged under media-controlled conditions. Surface ponding data was continuously measured using the HYDROS 21 sensor in each mesocosm. Surface ponding measurements were collected every 5 minutes instead of every 1 minute as specified in the QAPP because the shortest possible logging interval for the Meter sensors is 5 minutes.

Results from hydraulic conductivity testing are presented in **Figure *2***. Sensor drawdown data were analyzed to determine drawdown rate values by dividing the drawdown depth by the elapsed time for the portion of the drawdown curve with the steepest slope. Calculated drawdown rate values from Special Testing Event #3 are presented in Table 3 along with values from Special Testing Events #1 and 2. These values do not represent hydraulic conductivity values which account for several other factors. Hydraulic conductivity values will be calculated and presented in the Final Report.

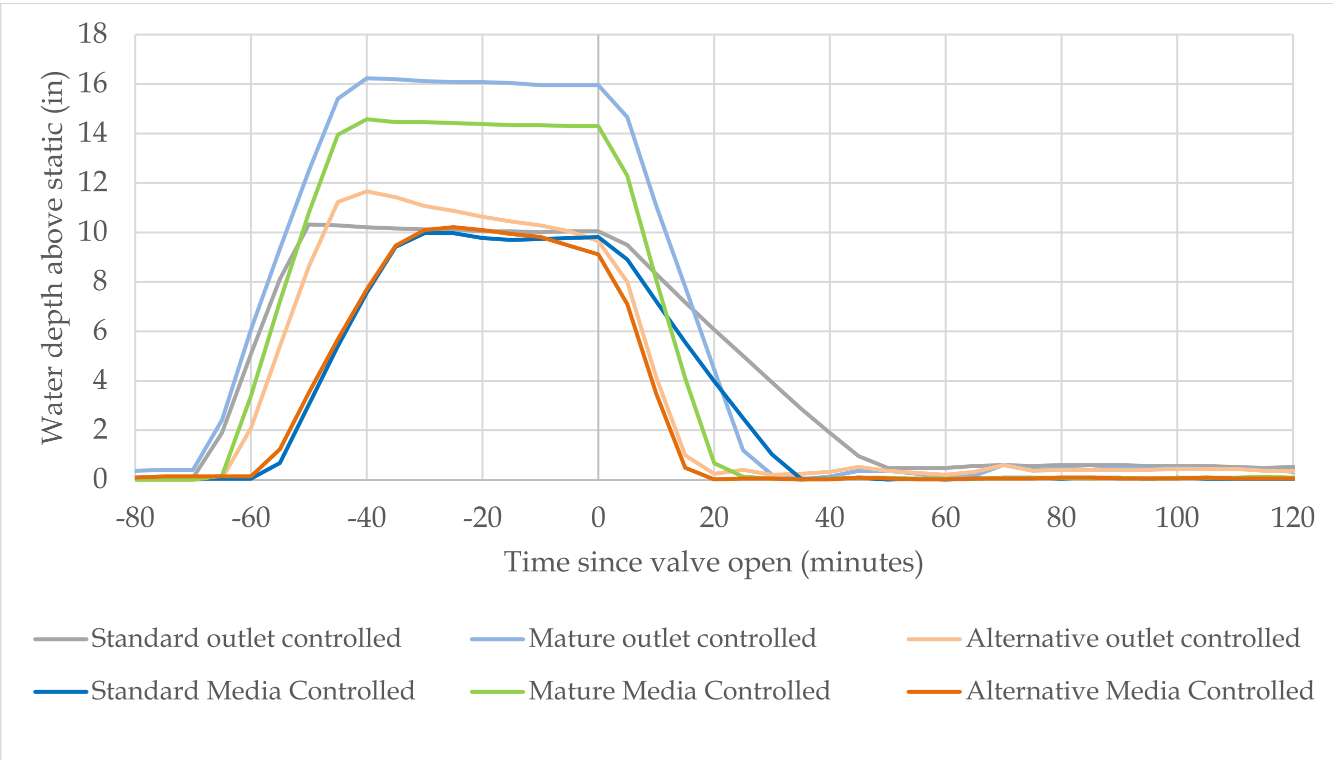

Figure 2: Hydraulic conductivity testing results

Table 3. Hydraulic conductivity analysis data

Mesocosm	**Special Event #3**			**Special Event #2**	**Special Event #1**
	Analysis Period (minutes)	**Drawdown Depth (inches)**	**Infiltration Rate (inches/hour)**	**Infiltration Rate (inches/hour)**	**Infiltration Rate (inches/hour)**
12: Standard BSM, outlet controlled	50	8.5	12.8	12.9	4.9

Mesocosm	Special Event #3			Special Event #2	Special Event #1
	Analysis Period (minutes)	Drawdown Depth (inches)	Infiltration Rate (inches/hour)	Infiltration Rate (inches/hour)	Infiltration Rate (inches/hour)
33: Standard BSM, media controlled	25	7.9	18.9	21.1	5.8
22: Mature BSM, outlet controlled	20	13.5	40.4	48.5	40.7
13: Mature BSM, media controlled	15	11.6	46.5	49.9	44.3
15: Alternative BSM, outlet controlled	10	7.0	42.0	41.6	41.3
34: Alternative BSM, media controlled	10	6.6	39.7	52.4	31.8

5 Vegetation Monitoring

Vegetation monitoring happened 3 times during this monitoring period. The first vegetation monitoring took place on 2/8/22 and consisted of height and base circumference measurements, along with a visual vigor rating from 1-5. During this vegetation monitoring event, it was determined that the mature dogwoods would need to be pruned to prevent shading the grasses. It was also determined that the dead grass and leaves from previous years growth would be removed from all mesocosms.

The second and third vegetation monitoring events revolved around this pruning and debris removal. The same height, base circumference and vigor ratings were taken on 3/31/22 (before pruning) and on 4/1/22 (after pruning).

6 Operations and Maintenance Monitoring

Operations and maintenance (O&M) monitoring consisted of monthly system checks including inspection of the outlet control orifices, checking inlet weir boxes for debris and cleaning, removing weeds and debris from mesocosms, cleaning and level checks of tipping bucket flow meters, inspecting ponding depth and soil moisture sensors, cleaning, and level checks of weather station equipment.

Orifice clogging was not observed during this monitoring period. During this period, removal of leaves, dead grass, and other debris was required for all treatments. Pruning of dogwoods was required in the mature mesocosms only.